

Section 9: Tsunami Hazards in the City of Long Beach

Why Are Tsunamis a Threat to Southern California?

Based on the historic record, the probability of a tsunami striking the City's coastal area is a very low threat. However, geologically the historic record is very short and recent studies of nearby offshore faults and marine landslide potential indicate that such events are likely to occur sometime in our future. If a tsunami should occur, the consequences would be great. The impact could cause loss of life, destroy thousands of high priced homes and greatly affect the City's downtown, port, marinas, coastal businesses, and impact tourism. Even if all residents and visitors were safely evacuated, the damage to property in this densely populated, high property value area would still be tremendous. In addition, certain areas within the City could be vulnerable to a seiche (inland tsunami) including Naples, the Port, and marinas.

California's Tsunamis

"Since 1812, the California coast has had 14 tsunamis with wave heights higher than three feet; six of these were destructive. The Channel Islands were hit by a big tsunami in the early 1800s. The worst tsunami resulted from the 1964 Alaskan earthquake and caused 12 deaths and at least \$17 million in damages in northern California."¹

What are Tsunamis?

The phenomenon we call "tsunami" (soo-NAH-mee) is a series of traveling ocean waves of extremely long length generated primarily by vertical movement on a fault (earthquake) occurring along the ocean floor. Underwater volcanic eruptions and landslides can also generate tsunamis. In the deep ocean, the tsunami waves move across the deep ocean with a speed exceeding 500 miles per hour, and a wave height of only a few inches. Tsunami waves are distinguished from ordinary ocean waves by their great length between wave crests, often exceeding 60 miles or more in the deep ocean and by the fact the wave extends from the bottom of the ocean to the surface. Typical waves are wind-generated and are near surface phenomena. Local tsunamis can be much shorter in wave length and much higher in amplitude.

As a tsunami reaches the shallow waters of the coast, the waves slow down and the water can pile up into a wall of destruction up to 30 feet or more in height. The effect can be amplified where a bay, harbor or lagoon funnels the wave as it moves inland. Large tsunamis have been known to rise over 100 feet. Even a tsunami 1-3 feet high can be very destructive and cause many deaths and injuries, especially within Port and harbor facilities.

What causes Tsunami?

There are many causes of tsunamis but the most prevalent is vertical fault movement during an earthquake at the surface of the ocean floor. In addition, marine landslides, underwater volcanic eruptions, explosions, and even the impact of cosmic bodies, such as meteorites, can generate tsunamis.

Plate Tectonics

Plate Tectonic theory is based on an earth model characterized by a small number of lithospheric plates, 40 to 150 miles thick, which float on a viscous under-layer called the asthenosphere. These plates, which cover the entire surface of the earth and contain both the continents and sea floor, move relative to each other at rates of up to several inches per year. The region where two plates come in contact is called a plate boundary, and the way in which one plate moves relative to another determines the type of boundary: spreading, where the two plates move away from each other; subduction, where the two plates move toward each other and one slides beneath the other; and transform, where the two plates slide horizontally past each other. Subduction zones are characterized by deep ocean trenches, and the volcanic islands or volcanic mountain chains associated with the many subduction zones around the Pacific Rim are sometimes called the Ring of Fire. Southern California is part of the Ring of Fire. Major faults in the region are a consequence of the collision of the Pacific Plate and the North American Plate.

Tsunamis

In general, tsunamis may be generated by sea floor faulting or marine landslides.

Faulting

Not all active faults generate tsunamis. To generate a tsunami, the fault where the fault on which the earthquake occurs must be underneath or near the ocean, and cause vertical movement of the sea floor over a large area, hundreds or thousands of square miles. "By far, the most destructive tsunamis are generated from large, shallow earthquakes with an epicenter or fault trace on the ocean floor."² The amount of vertical motion of the sea floor, the area over which it occurs, and the efficiency with which energy is transferred from the earth's crust to the ocean water are all part of the tsunami generation mechanism.

Marine Landslides

Alternatively, "Less frequently, tsunami waves can be generated from displacements of water resulting from rock falls, icefalls and sudden submarine landslides or slumps. Such events may be caused impulsively from the instability and sudden failure of submarine slopes, which are sometimes triggered by the ground motions of a strong earthquake. For example in the 1980's, earth moving and construction work of an airport runway along the coast of Southern France, triggered an underwater landslide, which generated destructive tsunami waves in the harbor of Thebes." This latter category of tsunami generation may be the greatest long term threat to Southern California. Recent studies at the University of Southern California Tsunami Research Center suggest the potential for the generation of large tsunamis from marine landslides off the Southern California coast as a result of earthquake shaking.

Tsunami Earthquakes

The September 2, 1992 Nicaragua Earthquake (magnitude 7.2) was barely felt by residents along the coast of Nicaragua. Located well off-shore, the severity of shaking on a scale of I to XII, was mostly II along the coast, and reached III at only a few places. Twenty to 70 minutes after the earthquake occurred, a tsunami struck the coast of Nicaragua with wave amplitudes up to 13 feet above normal sea level in most places and a maximum run-up height of 35 ft. The waves caught coastal residents by complete surprise and caused many casualties and considerable property damage.

This tsunami was caused by an earthquake on a fault in the ocean that produced an unusually large tsunami relative to the earthquake magnitude. Tsunami earthquakes are characterized by a very shallow focus, fault dislocations greater than several meters, and fault surfaces that are smaller than for a normal earthquake.

Two other destructive and deadly tsunamis from tsunami earthquakes have occurred in recent years in Java, Indonesia (June 2, 1994) and Peru (February 21, 1996).

Tsunami Characteristics

How Fast?

Unnoticed tsunami waves can travel at the speed of a commercial jet plane, over 500 miles per hour in the open ocean. They can move from one side of the Pacific Ocean to the other in less than a day. It has been recently estimated, that a locally generated tsunami could move across San Pedro Bay in one hour. This great speed makes it important to be aware of the tsunami as soon as it is generated. Scientists can predict when a tsunami will arrive at various places by knowing the source characteristics of the earthquake or marine landslide that generated the tsunami, real time data on the waves sent by instruments on the ocean floor by satellite to tracking stations and the characteristics of the sea floor along the paths to those places. Tsunamis travel much slower in more shallow coastal waters where their wave heights begin to increase dramatically.

How Big?

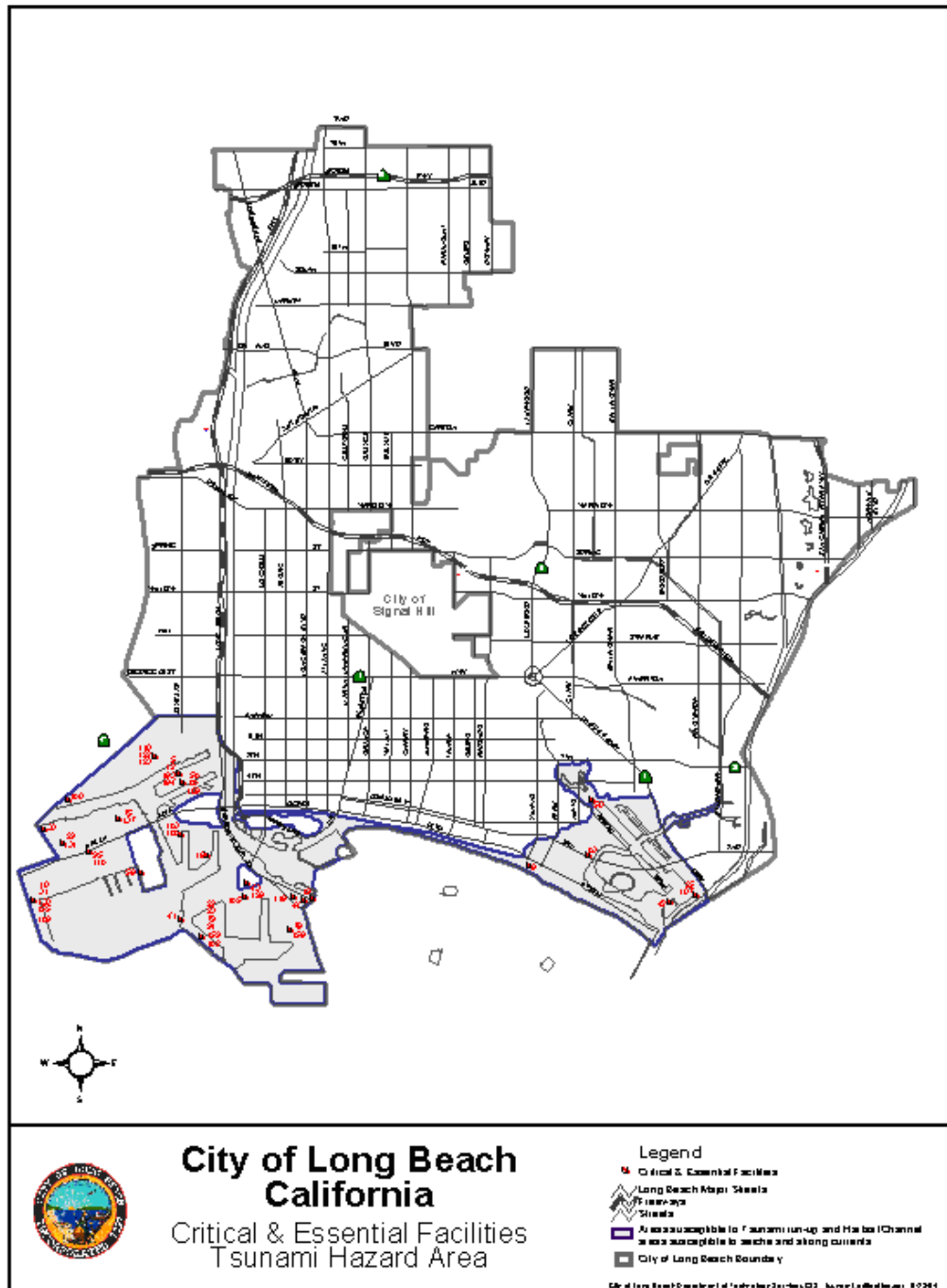
Offshore and coastal features can determine the size and impact of tsunami waves. Reefs, bays, entrances to rivers, undersea features and the slope of the beach all help to modify the tsunami as it attacks the coastline. When the tsunami reaches the coast and moves inland, the water level can rise many feet. In extreme cases, water level has risen to more than 50 feet for tsunamis of distant origin and over 100 feet for tsunami waves generated near the earthquake's epicenter. The first wave may not be the largest in the series of waves. Some predictions reveal that there could be 4 or more destructive waves over a period of 30 minutes or more. One coastal community may see no damaging wave activity while in another nearby community destructive waves

can be large and violent. The flooding can extend inland by 1000 feet or more, covering large expanses of land with water and debris.

How Frequent?

Since scientists cannot predict when earthquakes will occur, they cannot determine exactly when a tsunami will be generated. However, by looking at past historical tsunamis and run-up maps, scientists know where tsunamis are most likely to be generated. Past tsunami height measurements are useful in predicting future tsunami impact and flooding limits at specific coastal locations and communities.

Map 9-1: Facilities Map - Tsunami Hazard Area
(Source: City of Long Beach GIS)



Types of Tsunamis

Pacific-wide and Regional Tsunamis

Tsunamis can be categorized as “local” and Pacific-wide. Typically, a Pacific-wide tsunami is generated by major vertical ocean bottom movement in offshore deep trenches. A “local” tsunami can be a component of the Pacific-wide tsunami in the area of the earthquake or a wave that is confined to the area of generation within a bay or harbor and caused by movement of the bay itself or landslides.

The last large tsunami that caused widespread death and destruction throughout the Pacific was generated by an earthquake located off the coast of Chile in 1960. It caused loss of life and property damage not only along the Chile coast but also in Hawaii and as far away as Japan. The Great Alaskan Earthquake of 1964 killed 106 people and produced deadly tsunami waves in Alaska, Oregon and California.

In July 1993, a tsunami generated in the Sea of Japan killed over 120 people in Japan. Damage also occurred in Korea and Russia but spared other countries since the tsunami wave energy was confined within the Sea of Japan. The 1993 Japan Sea tsunami is known as a “regional event” since its impact was confined to a relatively small area. For people living along the northwestern coast of Japan, the tsunami waves followed the earthquake within a few minutes.

During the 1990's, destructive regional tsunamis also occurred in Nicaragua, Indonesia, the Philippines, Papua New Guinea, and Peru, killing thousands of people. Others caused property damage in Chile and Mexico. Some damage also occurred in the far field in the Marquesas Islands (French Polynesia) from the July 30, 1995, Chilean and February 21, 1996, Peruvian tsunamis.

In less than a day, tsunamis can travel from one side of the Pacific to the other. However, people living near areas where large earthquakes occur may find that the tsunami waves will reach their shores within minutes of the earthquake. For these reasons, the tsunami threat to many areas such as Alaska, the Philippines, Japan and the United States West Coast can be immediate (for tsunamis from nearby earthquakes which take only a few minutes to reach coastal areas) or less urgent (for tsunamis from distant earthquakes which take from three to 22 hours to reach coastal areas).

History of Regional Tsunamis

Local

The local tsunami may be the most serious threat as it strikes suddenly, sometimes before the earthquake shaking stops. Alaska has had six serious local tsunamis in the last 80 years and Japan has had many more.

Local History of Tsunamis

Tsunamis have been reported since ancient times. They have been documented extensively in California since 1806. Although the majority of tsunamis have occurred in Northern California, Southern California has been impacted as well. In the 1930's, four tsunamis struck the Los Angeles and Orange Counties, as well as along San Diego's coastal areas. In Orange County the tsunami wave reached heights of 20 feet or more above sea level. In 1964, following the Alaska 8.2 earthquake, tidal surges of approximately 4 feet to 5 feet hit the Huntington Harbor area causing moderate damage.

Personal Interview

Name: Bill Richardson
Title: City of Huntington Beach Lifeguard
Year: 1964 – Alaska Good Friday Earthquake and Tsunami
(paraphrased by Gloria Morrison)

I was on the lifeguard in the tower on the pier. We received warning by phone from the Fire Department who had received information from the National Weather Service. We were told to tell folks on the pier and beach that if the situation escalated they would be advised to evacuate the area and that they should be prepared to move quickly.

I witnessed heavy tidal surges on the beaches. The tide changed in 10 minutes from what it normally was to a very different tide. Normally it takes six hours to change and in 10 minutes it sucked water out and when it came in, it went over the berm, $\frac{3}{4}$ of the way across the beach. The accelerated tide within one hour came and went twice. The highs were extreme and the lows were extreme, very like our astronomical tides. I monitored the radio and heard of all the docks breaking loose in the harbor. The current was so strong and movement of water that the radio was being overwhelmed with calls for response. Only the two islands of Admiralty and Gilbert existed at the time.

Bill Richardson referred me to Walt Snyder, a Lifeguard Lt. at the time. Walt was in Huntington Harbor during this event.

Personal Interview

Name: Walt Snyder
Title: City of Huntington Beach City Lifeguard, Lt. in the Harbor
Year: 1964 – Alaska Good Friday Earthquake and Tsunami
(paraphrased by Gloria Morrison)

I was called out at daybreak due to the tidal surges in the Huntington Harbor. I got in the City's only rescue boat. The tidal surges were huge and making whirlpools. They were moving at a much faster and higher rate than normal tide.

When the surges would come in, they would tear the boats away from their moorings. Then when the surges would go out, they would take the boats

through the bridge at Pacific Coast Highway to the Seal Beach (Anaheim Landing Bridge) and when they hit the pilings it would tear the boats apart. The high tides were carrying the boats into the weapons station. When surges retreated, the boats would end up on dry land at the weapons station --- high and dry and broken up.

In 1964 there were only about 200-300 boats in the harbor and today Walt estimated there are 3,500 plus boats. There were only 300-400 homes then and now he estimates an excess of 5,000. This occurred during a low tide. The sea wall in Huntington Harbor is 9'. Had this occurred during a high tide, Walt stated the surges would have easily gone over the sea walls and damaged many homes.

Table 9-1 Tsunami Events in California 1930-2004

Tsunami Events In California 1930-2004			
Date	Location	Maximum Run up*(m)	Earthquake Magnitude
08/31/1930	Redondo Beach	6.10	5.2
08/31/1930	Santa Monica	6.10	5.2
08/31/1930	Venice	6.10	5.2
03/11/1933	La Jolla	0.10	6.3
03/11/1933	Long Beach	0.10	6.3
08/21/1934	Newport Beach	12.00	Unknown
02/09/1941	San Diego	Unknown	6.6
10/18/1989	Monterey	0.40	7.1
10/18/1989	Moss Landing	1.00	7.1
10/18/1989	Santa Cruz	0.10	7.1
04/25/1992	Arena Cove	0.10	7.1
04/25/1992	Monterey	0.10	7.1
09/01/1994	Crescent City	0.14	7.1
11/04/2000	Point Arguello	5.00	
Source: Worldwide Tsunami Database www.ngdc.noaa.gov			

* Maximum Run-Up (M)-The maximum water height above sea level in meters. The run- up is the height the tsunami reached above a reference level such as mean sea level. It is not always clear which reference level was used.

Tsunami Hazard Assessment

Hazard Identification

According to the City's General Plan Public Safety Element, the threat of significant damage associated with a tsunami is considered to be low to moderate. The Element includes the following section on the topic of tsunamis:

"A tsunami is a sea wave usually generated by a large submarine earthquake. A seiche is similar to a tsunami, but is generated in an enclosed body of water such as a harbor, lake, or swimming pool. The potential damage, of course, is much greater from a tsunami than a seiche. Tsunamis travel across the ocean as long, low waves.

Traveling at almost 500 mph in the Pacific, such a wave in the open causes no problems, and, in fact, the slope of the wave front may be imperceptible to a ship at sea. However, as the tsunami approaches the coastline, it is affected by shallow bottom topography and the configuration of the coastline which transform it into very high and potentially devastating waves. If large waves do not occur, strong currents can cause extensive damage. By comparison to many other areas of southern California, Long Beach is somewhat protected by the surrounding geography and the breakwater. As a substantial warning time of perhaps as much as 6 to 12 hours would be anticipated, the potential for death or injury from a tsunami is not considered great. Substantial shoreline property damage would likely occur, however. Major damage would be to boats, harbor facilities and sea-front structures. In terms of probability, published estimates of recurrence intervals indicate maximum wave heights of 3 to 6 feet for 50 and 100 year recurrence intervals."

It's important to note that the General Plan's Public Safety Element was last updated when the scientific community felt a tsunami could not be generated locally offshore. This concept is now being reexamined. Warning times and magnitudes could be considerably greater than those posed by a distant tsunami. As an example, the warning time for coastal areas would be measured in minutes, not hours.

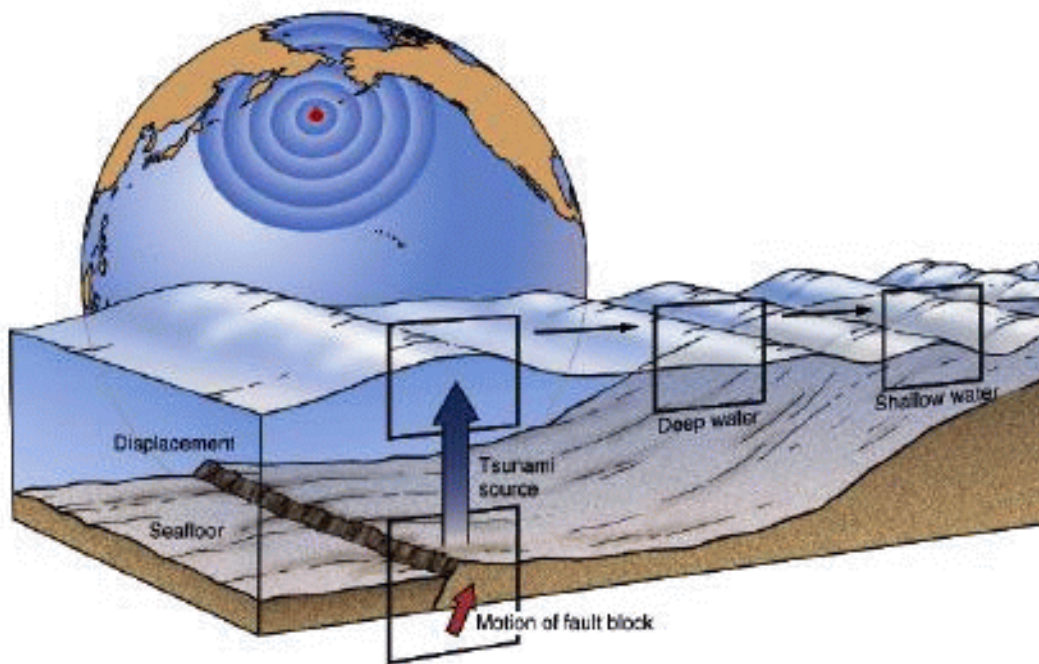
Damage Factors of Tsunamis

Tsunamis cause damage in three ways: inundation, wave impact on structures, structural fires, and erosion.

"Strong, tsunami-induced currents lead to the erosion of foundations and the collapse of bridges and sea walls. Flotation and drag forces move houses and overturn railroad cars. Considerable damage is caused by the resultant floating debris, including boats and cars that become dangerous projectiles that may crash into buildings, break power lines, and may start fires. Fires from damaged ships in ports or from ruptured coastal oil storage tanks and refinery facilities can cause damage greater than

that inflicted directly by the tsunami. Of increasing concern is the potential effect of tsunami draw down, when receding waters uncover cooling water intakes of nuclear power plants.”³

Figure 9-1: Tsunami Formation



According to the Tsunami Run-up Maps for nearby coastal communities, the entire coastline would be significantly to severely impacted by a tsunami. During the summer months (August), the City of Long Beach can attract over 17,000 people a day. In addition there are approximately 100 shipping lines in its harbor. If a tsunami were to occur it could devastate the entire coastal area.

Tsunami Watches and Warnings

Warning System

The tsunami warning system in the United States is a function of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service. Development of the tsunami warning system was impelled by the disastrous waves generated in Alaska in April 1946, which surprised Hawaii and the U.S. West Coast, taking a heavy toll in life and property.

The disastrous 1964 tsunami resulted in the development of a regional warning system in Alaska. The Alaska Tsunami Warning Center is in Palmer, Alaska. This facility is the nerve center for an elaborate telemetry network of remote seismic stations in Alaska, Washington, California, Colorado, and other locations. Tidal data is also telemetered directly to the ATWC from eight Alaskan locations. Tidal data from Canada, Washington, Oregon, and California are available via telephone, teletype, and computer readout.

Notification

The National Warning System (NAWAS) is an integral part of the Alaska Tsunami Warning Center. Reports of major earthquakes occurring anywhere in the Pacific Basin that may generate seismic sea waves are transmitted to the Honolulu Observatory for evaluation. An Alaska Tsunami Warning Center is also in place for public notification of earthquakes in the Pacific Basin near Alaska, Canada, and Northern California. The Observatory Staff determines action to be taken and relays warnings over the NAWAS circuits to inform and warn West Coast states. The State NAWAS circuit is used to relay the information to the Los Angeles County Operational Area warning center which will in turn relay the information to local warning points in coastal areas. The same information is also transmitted to local jurisdictions over appropriate radio systems, teletype, and telephone circuits to ensure maximum dissemination.

Los Angeles County will use the Emergency Alert System (EAS) and Emergency News Network (ENN) to warn the public about an anticipated tsunami.

A Tsunami Watch Bulletin is issued if an earthquake has occurred in the Pacific Basin and could cause a tsunami. A Tsunami Warning Bulletin is issued when an earthquake has occurred and a tsunami is spreading across the Pacific Ocean. When a threat no longer exists, a Cancellation Bulletin is issued.

Vulnerability and Risk

With an analysis of tsunami events depicted in the “Local History” section, we can deduce the common tsunami impact areas will include impacts on life, property, infrastructure and transportation.

Community Tsunami Issues

What is Susceptible to Tsunami?

The possibility of a tsunami impacting the City of Long Beach has not been fully examined. A thorough investigation of the likelihood and impacts of a tsunami on the Long Beach coastline is worthy of consideration. Once the vulnerabilities are better understood, the City should consider updating its emergency response plans and re-train its response staffs, as needed.

Life and Property

Based on the “local” history events of tsunamis we can conclude that approximately 1% of the City would be heavily impacted. The largest impact on the community from a tsunami event would be from loss of and property damage to infrastructure.

Using the Tsunami Warning and Watch Bulletin would provide time to allow coastal residents to evacuate and seek higher ground for shelter. This would greatly reduce injuries and loss of life.

Development

The most significant impacts would be in the following areas:

- ✓ Port and surrounding commercial facilities at or near sea level.
- ✓ Downtown Marina and structures in the Old Pike area.
- ✓ Naples and Belmont Shore area.
- ✓ Coastal bridges and exposed infrastructure
- ✓ Power plants near the shoreline

Coastal Property

Property along the coast could also be devastated. City of Long Beach coastal area is home to millions of dollars worth of industrial and commercial structures. In addition, the area is scattered with infrastructure that serves the entire coastal region. A large tsunami could potentially destroy or damage hundreds of commercial and industrial facilities. A tsunami could have a catastrophic impact on the Port of Long Beach and the overall economy.

Industrial properties in and near the Port of Long Beach would be significantly impacted – perhaps for an extended period of time. Additionally, the ships in the harbor and the supportive facilities on shore could be damaged and negatively impacted.

During summer months up to tens of thousands people a day come into the community to stay in the hotels and shop at coastal shopping facilities. The local government relies heavily on tourism and sales tax. A tsunami event could impact businesses by damaging property and by interrupting business and services. Any residential or commercial structure with weak reinforcement could be susceptible to damage.

The lack of an adequate local warning system could further jeopardize loss of lives and property.

Infrastructure

Tsunamis (and earthquakes) can damage buildings, power lines, and other property and infrastructure due to flooding. Tsunamis can result in collapsed or damaged buildings or blocked roads and bridges, damaged traffic signals, streetlights, and parks, among others. Damage to public water and sewer systems, transportation networks, and flood channels would greatly impact daily life for residents.

Roads blocked by objects during a tsunami may have severe consequences to people who are attempting to evacuate or who need emergency services. Emergency response operations can be complicated when roads are blocked or when power supplies are interrupted. Industry and commerce can suffer losses from interruptions in electric services and from extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from tsunamis related to both physical damages and interrupted services.

End Notes

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1. http://education.sdsc.edu/optiputer/htmlLinks/california_tsunami.html
 2. [Hhttp://www.prh.noaa.gov/itic/library/about_tsu/faqs.html#1H](http://www.prh.noaa.gov/itic/library/about_tsu/faqs.html#1H)
 3. Ibid